

602705

2 of 3

MEMORANDUM

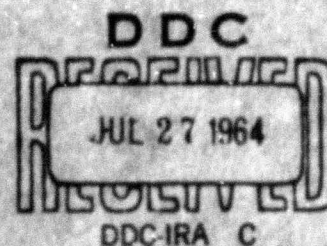
RM-4156-PR

JULY 1964

40 p \$2.00 lc
\$0.50 mf

CYBERNETICS AND ITS DEVELOPMENT IN THE SOVIET UNION

Roger Levien and M. E. Maron



PREPARED FOR:

UNITED STATES AIR FORCE PROJECT RAND

The RAND Corporation
SANTA MONICA • CALIFORNIA

**BLANK PAGES
IN THIS
DOCUMENT
WERE NOT
FILMED**

MEMORANDUM

RM-4156-PR

JULY 1964

CYBERNETICS AND ITS DEVELOPMENT IN THE SOVIET UNION

Roger Levien and M. E. Maron

This research is sponsored by the United States Air Force under Project RAND - Contract No. AF 19(638)-700 monitored by the Directorate of Development Plans, Deputy Chief of Staff, Research and Development, Hq USAF. Views or conclusions contained in this Memorandum should not be interpreted as representing the official opinion or policy of the United States Air Force.

DDC AVAILABILITY NOTICE

Qualified requesters may obtain copies of this report from the Defense Documentation Center (DDC).

The **RAND** *Corporation*

1700 MAIN ST. • SANTA MONICA • CALIFORNIA • 90406

PREFACE AND SUMMARY

This Memorandum is intended as an introduction to the subject of cybernetics, with special reference to its origins and ramifications in the United States and its subsequent development in the Soviet Union. As a survey document only, it should be of interest primarily to non-experts in the field; it has been prepared to provide a non-scientific audience with sufficient background to facilitate appreciation of the potential impact of cybernetics on science and society.

The inclusion of a survey of Soviet cybernetics is in response to an awareness by many researchers, government officials, and military men in this country, that cybernetics has become a subject of intense interest and activity in the Soviet Union. As in the United States, scientific research, military applications, economic planning, education, industry, etc., are affected by developments in cybernetics. Thus, it is important to understand current Soviet attitudes towards cybernetics and the impact of these attitudes on their economic and social system.

Following a brief introduction, the Memorandum traces the birth of cybernetics and sketches its early development and its growth and emergence in the West. The second half of the Memorandum examines Soviet cybernetics.

CONTENTS

PREFACE and SUMMARY	iii
Section	
I. INTRODUCTION	1
II. ORIGINS AND SCOPE OF CYBERNETICS	2
Norbert Wiener and Cybernetics	2
The Theory of Information	6
Computer Technology and Applications ..	8
Development of Digital Technology ...	8
Development of Theory	9
Computer Applications	9
Neurophysiology and Artificial	
Intelligence	10
The Brain and the Computer	10
Artificial Intelligence	11
Cybernetics and the Social Sciences ...	13
Concluding Remarks	14
III SOVIET CYBERNETICS	15
Difference and Importance	15
History	17
Promise and Problems	24
BIBLIOGRAPHY	33

To live effectively is to live with adequate information. Thus communication and control belong to the essence of man's inner life, even as they belong to his life in society.

--Norbert Wiener

I. INTRODUCTION

There has been an increased awareness recently, particularly among non-scientists in government, of the current interest and heightened activity in the field of cybernetics in the Soviet Union. The purpose of this Memorandum is to apprise those interested in the subject, especially in government, of the development, present status, and potential impact of Soviet cybernetics. The emphasis is two-fold: first, and primarily for the non-expert, we want to tell what cybernetics is about and how it has developed in the West; then, we wish to describe the rise of cybernetics in the Soviet Union and the status, emphasis, and direction of current Soviet work in cybernetics.

This paper is a preliminary discussion and an overview. It is tutorial in nature and clearly is not intended as a thorough discussion of the subject; a more detailed and comprehensive analysis of the status of cybernetics and its impact on Soviet society will be forthcoming. The present paper is offered in the interest of timeliness. Further detail about several aspects of cybernetics in the Soviet Union is contained in the documents listed in the bibliography at the end of this paper.

The section on the origins and development of cybernetics was written by M. E. Maron; the section on cybernetics in the Soviet Union was written by Roger Levien.

II. ORIGINS AND SCOPE OF CYBERNETICS

NORBERT WIENER AND CYBERNETICS

Cybernetics denotes many things to many people and, even among the experts, there is no complete and precise agreement as to its subject content. The purpose of this section is to characterize cybernetics as we see it. And perhaps there is no easier way to introduce the subject of cybernetics than by way of the late Norbert Wiener's introduction to his now classic book on the subject, which was first published in 1948.*

In that introduction Wiener wrote that the ideas for cybernetics grew out of his participation in a seminar on the methodology of science. The other participants in this seminar were from diverse fields, and their participation reflected their common belief that new and exciting areas for scientific exploration lay in the no-man's lands between established fields. And they believed furthermore that the problems encountered there could be attacked successfully only by teams of scientists from different fields of specialization.

The onset of World War II involved Wiener in an attack on just such a multidisciplinary problem; viz., the problem of designing an automatic system that would enable aircraft-tracking radar data to be fed to a computer that could predict the future course of the aircraft being tracked and control the aiming of guns so as to shoot down the

* Wiener, Norbert, Cybernetics: Or Control and Communication in the Animal and the Machine, John Wiley and Sons, Inc., New York, 1948.

moving target. Thus, Wiener found himself, together with Julian Bigelow,^{*} engaged in a study of the theory of prediction and the construction of machines that could embody the theory. "Mr. Bigelow and I came to the conclusion that an extremely important factor in voluntary activity is what the control engineers term feed-back."[†] The actual output of a system is compared with some desired output (the goal) and information about the "mismatch" is fed back to the controller (command generator) so as to modify subsequent outputs. If the feedback is negative, the command signals drive the output ever closer to the goal; if the feedback is positive, they do the reverse.

Just as excessive or insufficient feedback can cause "hunting" and instability in automatic control systems (about which there is now a sound mathematical theory), so also Wiener and his colleagues conjectured that the human control mechanisms for motor activity could suffer from improper feedback. They approached a neurophysiologist and asked whether there is "any pathological condition in which the patient, in trying to perform some voluntary act like picking up a pencil, overshoots the mark, and goes into an uncontrollable oscillation."[‡] The answer was yes, the condition is called "purpose tremor" and is often associated with an injury to the cerebellum.

^{*} Julian Bigelow is a mathematician, now at the Institute for Advanced Study at Princeton, who was an early collaborator of Wiener.

[†] Ibid., p. 13. (All quotes in this section are from the Introduction to Cybernetics, op. cit.)

[‡] Ibid., p. 15.

"We thus found a most significant confirmation of our hypothesis concerning the nature of at least some voluntary activity. It will be noted that our point of view considerably transcended that current among neurophysiologists. The central nervous system no longer appears as a self-contained organ, receiving inputs from the senses and discharging into the muscles. On the contrary, some of its most characteristic activities are explicable only as circular processes, emerging from the nervous system into the muscles, and re-entering the nervous system through the sense organs, whether they be proprioceptors or organs of the special senses. This seemed to us to mark a new step in the study of that part of neurophysiology which concerns not solely the elementary processes of nerves and synapses but the performance of the nervous system as an integrated whole."*

This led to the recognition that an analysis of control problems involves an analysis of the underlying communication problems and the latter, in turn, center around the fundamental concept of the message--whether it be transmitted mechanically, electrically, or chemically, whether in artificial systems or in the human nervous system. Wiener goes on to say that these considerations relating to communication of messages led him to look at the concept of noise and at questions of a statistical nature akin to some found in statistical mechanics. "Just as the amount of information in a system is a measure of its degree of organization, so the entropy of a system is a measure of its degree of disorganization...."[†] This led to a statistical theory of information.

* Ibid., p. 15.

[†] Ibid., p. 18.

"Thus [writing in 1948 Wiener states] as far back as four years ago, the group of scientists about Dr. Rosenblueth and myself had already become aware of the essential unity of the set of problems centering about communication, control, and statistical mechanics, whether in the machine or in living tissue. On the other hand, we were seriously hampered by the lack of unity of the literature concerning these problems, and by the absence of any common terminology, or even of a single name for the field. After much consideration, we have come to the conclusion that all the existing terminology has too heavy a bias to one side or another to serve the future development of the field as well as it should; and as happens so often to scientists, we have been forced to coin at least one artificial neo-Greek expression to fill the gap. We have decided to call the entire field of control and communication theory, whether in the machine or in the animal, by the name Cybernetics...."*

Wiener goes on to describe the relationships of other subjects to the broad field of cybernetics; e.g., neurophysiology and information processing in the cerebral cortex, mathematical logic and its application to the analysis of neural switching circuits, computers and their use in constructing models of brain mechanisms, etc. Thus, we find in his book the groundwork and beginnings of a broad interdisciplinary study of all phases of information processing and control systems and of the implications and ramifications of this for such subjects as the psychology of perception, psychiatry and memory disorders, linguistics and sociology. Much work has been conducted in the field of cybernetics since it erupted on the scientific scene 15 years ago, and we shall look briefly at some of it.

* Ibid., p. 19.

THE THEORY OF INFORMATION

If we take cybernetics to encompass those sciences, studies, techniques, and mechanisms that relate to complex communication and control systems (whether in man, machine, or society itself), then we must recognize the central role played by the concept of information. In 1948, a theoretical foundation for a theory of information, authored by Dr. Claude Shannon, a mathematician who, incidentally, had been a student of Wiener, appeared in the pages of the Bell System Technical Journal.^{*} Here for the first time was a precise quantitative explication for one measure of the amount of information contained in a message. Given this theory, it was then possible to answer such questions as: How much more information can be conveyed over communication system A than system B? That is, the theory allowed one to define precisely the capacity of a communication link (as well as the capacity of an information store). Shannon's theory provided the tools for determining the amount of information generated by an information source (real or artificial). The important notion of a code[†] for conveying messages was treated in a formal way so that one could talk of the efficiency of a given coding system. And one could decide whether any particular coding system (relative to a given information source) was the best

^{*}The article is reprinted in: Shannon, C. E., and Warren Weaver, The Mathematical Theory of Communication, University of Illinois Press, Urbana, Illinois, 1949.

[†]A code in this sense is meant as a sequence of symbols for representing a message.

possible one or not. Shannon's theory went on to clarify the key concept of noise and to show how redundancy could be introduced in coding schemes so as to combat the destructive effects of noise on information. And finally, he proved some very interesting and surprising relationships that hold among noise, redundancy, channel capacity, and error-free transmission of messages.

Here, then, was a precise language and a set of concepts tailored for the analysis of information systems. It has proven of great value in the engineering of communication systems, but since the emergence of Shannon's theory of communication in 1948, the terms and the language (but not often the corresponding theorems) also have been taken up and used by scientists in fields far different from the engineering of telephone systems. We find the language of information theory in papers dealing with subjects ranging from psychology and linguistics to genetics and neurophysiology.

Here it must be pointed out that messages conveying information have many properties, and Shannon's theory provides a measure for only one of these, namely, the statistical rarity of a message. A more general theory of information must eventually provide measures for such message properties as complexity, accuracy, precision, and, most important of all, semantic-pragmatic information content. The amount of semantic-pragmatic content conveyed by a message must surely be a function of the amount by which the message changes what a receiver knows (or believes). And that brings us to the problem of describing formally what a man knows. Although approaches to this problem have been made, much clarification is still needed.

COMPUTER TECHNOLOGY AND APPLICATIONS

Since digital computers are mechanisms for the physical and logical processing of information, they occupy a sizable part of the cybernetic stage. Further, the study of digital computers is a broad discipline comprehending not only digital technology and the theory of computer design and organization, but also many facets of computer application. It is the purpose of this section to describe briefly some of the ramifications of the computer field so as to indicate the diversity of subjects that may be brought under the general cybernetics umbrella.

Development of Digital Technology

Just after World War II and the publication of Cybernetics and Shannon's Mathematical Theory of Communication, there started an almost explosive growth in the development of digital computer technology. Some digital machines were developed during the war under wraps of secrecy, but once knowledge of computers, their components, and their potentials became generally available, there was a race to develop new computer components and circuitry and new types of information storage media. And in the decade or so since 1950, there has been rapid development and refinement of very-high-speed circuits and switching components, and comparable gains in the perfection of large-capacity, rapid-access data storage media. Finally, associated with these developments, there have appeared a host of sophisticated input-output and conversion equipments to aid in the task of communicating with computers.

Development of Theory

While the component and systems engineers were pushing rapidly ahead, their more theoretically oriented colleagues were working at the corresponding theory of information machines and automata. This includes both the science of computer circuit design and what is still the art of computer system design and organization. Along with these developments has come the beginning of a theory of reliability, whose concern is the question of how best to organize a large number of unreliable computing components to do a particular job in such a way that the system as a whole is extremely reliable. Thus, reliability theory has to do with the efficient use of redundant codes, components, and circuits to improve the overall reliability of a complex system. Other theoretical aspects of computer organization have to do with programming theory, development of new computer languages, and the theory of algorithms.*

Computer Applications

Turning now to the question of computer applications, we see a mass of information situations where automatic computers can be introduced completely, or partially, to mechanize the procedures involved. There are, of course, applications ranging from scientific calculations, automatic process control, teaching machines, and navigation and

* An algorithm is a complete, explicit, detailed, and unambiguous description of a procedure for going from a given problem to its solution (it might be thought of as a detailed recipe).

guidance, to business and medical data processing (automatic medical diagnosis), and, of great potential value, language data handling, as exemplified by information retrieval (the automation of search and retrieval of relevant documents) and language translation (the automatic translation from one natural language to another by means of a computing machine).

One of the most interesting uses for computers is in simulation and modeling of complex information processing situations: for example, the use of computers to simulate human problem-solving behavior, to simulate the behavior of complex neural-like nets so as to exhibit properties of learning and pattern recognition, and to simulate certain aspects of the information flow in a factory or in certain sectors of the national economy.

NEUROPHYSIOLOGY AND ARTIFICIAL INTELLIGENCE

The Brain and The Computer

Since Wiener first made a number of very suggestive analogies between the brain and the digital computer, there have been numerous comparisons of those two types of information processing systems. Grossly simplified comparisons between natural devices (i.e., neurons) and computer switching devices have been made in order to show that from a logical point of view, both kinds of switches process information in very similar ways. It has been suggested that the coding of information within the brain is essentially digital (i.e., having only discrete values), or perhaps is a hybrid analog-digital form of coding. We do

know that the overall logical organization of the brain is vastly different from that of a conventional digital computer; the circuitry of the brain is highly redundant and there is much parallel information processing.

Such contrasts and comparisons have been made since the inception of cybernetics and it has been felt by some that cybernetics could offer a new way to look at the problem of the brain. More specifically, the central hypothesis of cybernetics asserts, in effect, that the key mechanisms underlying purposeful motor activity can be explained mechanically in terms of feedback and control. And the more enthusiastic scientists have suggested that the principles of feedback and control can also account for so-called "higher mental functions," such as complex problem solving.*

Thus, the literature of cybernetics has provided impetus to apply the concepts of information and control theory to an analysis of brain organization. Researchers have applied these notions in formulating theoretical brain-like models and there have also been attempts to simulate aspects of such models on general-purpose digital computers.

Artificial Intelligence

An "intelligent machine" is one that can solve new and different problems, using new and different methods of

* For a discussion of the relationship between brain activity and thinking, see: Maron, M. E., On Cybernetics, Information Processing, and Thinking, The RAND Corporation, P-2879, March 1964.

solution; it is a mechanism that can learn from experience so as to use past information to modify its present responses and its preparations for the future. Intelligent behavior can be analyzed most generally in terms of problem-solving behavior, and the study of artificial intelligence is the study of the mechanisms and processes that can underlie problem-solving behavior in a wide variety of different problem situations.

The problem of artificial intelligence has been attacked along two quite different directions--both of which, however, involve the use of the digital computer as a tool for simulation.* One line of approach follows, in a sense, neurophysiology and attempts to model the known aspects of the informationally relevant structure of the brain. The simulated neuron-like elements can be connected together into networks and given suitable modification rules so that they exhibit pattern recognition and learning behavior. The other avenue of approach follows, in a sense, behavioristic psychology and attempts to simulate the problem-solving behavior of humans in the course of some problem situation. In the latter case, workers have constructed computer routines that will permit a digital computer to simulate many of the behavioral aspects of problem solving for board games such as chess; and, in the case of logic, to simulate the way that a human might derive the proof of a theorem.

* For a discussion of artificial intelligence and its relationships to other disciplines, see: Maron, M. E., Artificial Intelligence and Brain Mechanisms, The RAND Corporation, RM-3522-PR, March 1963.

CYBERNETICS AND THE SOCIAL SCIENCES

Wiener has said that society can only be understood through a study of the messages and the communication facilities which belong to it. He believed (as do others) that complex systems which depend for their functioning on information are susceptible to the same kind of a cybernetic information-flow analysis--whether the system in question be a control computer, a nervous system, or society itself. If an information-flow analysis of society is applicable, then insights gained from the study of how computing systems malfunction with the breakdown of certain information paths (or rates) might shed light on causes of similar symptoms of malfunction in society. Consider, as an example; the instabilities in the form of cyclical booms and busts in the national economy: Would it be possible to look at the relationships between labor, production, costs, pricing, investment, etc., so as to come up with an information-flow description which would correctly model the relevant aspects of the national economy? If so, then perhaps its instabilities could be cured in the same ways that an engineer cures instabilities in a complex control system (e.g., a guided missile) that suffers from improper feedback or inadequate processing of information.

Thus, it has been suggested that the concepts of cybernetics and its methods of analysis can be extended beyond computing and control systems and that they can have a potential impact toward the development of a new scientific study of economics and society.

CONCLUDING REMARKS

In summary then, cybernetics is a broad, rather all-inclusive set of studies dealing with problems of information and control--in man, machines, and allegedly even in society. But, as yet, it is a set of related studies and not a unified discipline. The only real unity has to do with the unity in its language--the language of information and control--and, in a sense, a unity in its methods for analyzing complex systems in terms of the flow and processing of information. However, since there are as yet no real, substantive, underlying laws, cybernetics does not enjoy a completely favorable reputation in the United States. Partially, of course, this lack of favor has been a result of exaggerated pronouncements and predictions put forth by the more enthusiastic workers in cybernetics.

But now let us look at the status of cybernetics in the Soviet Union, where it has universality and prestige far beyond anything it enjoys in our country.

III. SOVIET CYBERNETICS

DIFFERENCE AND IMPORTANCE

In the Soviet Union cybernetics has followed a course that is almost diametrically opposite from the one that it has followed in the West. Whereas in the West Wiener's ideas were greeted with enthusiasm but are now viewed with mixed emotions, in the Soviet Union Wiener's ideas were originally greeted coldly but have now been accepted (with some exceptions) enthusiastically and at the highest levels of science and government. The Soviets use the term "cybernetics" with the widest possible scope, embracing studies ranging from control theory to mathematical economics, from computer theory to artificial intelligence, from information theory to military command and control. The subject of cybernetics has drawn to its study some of the most prominent logicians, mathematicians, and engineers in the Soviet Union, many of the Academicians of the Soviet Academy of Sciences, and faculty members of the leading universities in, among others, Moscow, Leningrad, Kiev, and Novosibirsk. The number of periodicals, books, and conferences on cybernetics has increased greatly in the last few years.

The widespread enthusiasm, rapid growth, high-level support, and serious scientific interest in cybernetics in the Soviet Union would, by themselves, be reason enough for the West to pay careful heed to its progress; but there are three other reasons why the West should pay it especially close attention.

First, under the wide interpretation that the Soviets give it, cybernetics comprises many fundamental areas of

contemporary science and technology. Soviet computing, guidance and control, and developments in communications systems fall, in large measure, under cybernetics. Operations research, systems analysis, management control and information systems, and mathematical economics are all studied under its purview. Bionics (which is the study of information processing in insects, reptiles, fish, and other biological systems), artificial intelligence, pattern recognition, theory of nerve nets, and computational linguistics are still other branches of Soviet cybernetics. It is apparent that in the scientific-technological race in which we and the Soviets are engaged, it is essential to keep close watch on their investigation and exploitation of cybernetics.

Second, cybernetics as practiced in the Soviet Union has implications not only for general and basic areas of science and technology, but also for specific and applied areas of military operations and technology. Military cybernetics is an established sub-domain of the larger area of study. Guidance of missiles and aircraft, military computer applications, intelligence data processing, operations research, strategic analysis, and command and control all fall under that heading.

And there is a third, perhaps the most important, reason for the West to follow Soviet cybernetics closely: Cybernetics is a science with ideological implications that contradict and challenge the basic tenets of Soviet Marxism-Leninism. The Soviet politicians and ideologists face a difficult task in enjoying the fruits that the computer, control, and information sciences can produce

in automation, military technology, and control of the economy, without suffering from the "poisons" that they can release in economics, philosophy, psychology, and sociology. The ideologists have recognized the problem they face; many conferences, books, and articles have been devoted to the philosophical problems of cybernetics. Studies of the influence of cybernetics on Marxism-Leninism should, therefore, form an important part of Western studies of the evolution of Soviet society.

HISTORY

Some appreciation of the thrust and direction of Soviet cybernetics may be gained from a skeleton chronology of its development.

Wiener's book Cybernetics was first published in 1948. Its birth in the West, its non-Communist author, and the strict adherence to the dogma according to Stalin, encouraged in those years, all combined to enable it to go essentially unnoted in the Soviet Union for five years. The history of Soviet cybernetics begins in 1953.

Three significant events occurred in that year: cybernetics was the object of an anonymous attack in the prestigious ideological journal Questions of Philosophy [Voprosy filosofii]; one of the first Soviet computers, the BESM,^{*} was completed; and Stalin died.

The attack on cybernetics appeared in the section of Questions of Philosophy devoted to critiques of bourgeois

^{*}The MESM computer, perhaps an experimental prototype, was completed in 1951.

ideology. Under the heading "Whom Does Cybernetics Serve?"* its author, hiding behind an unusual anonymous title-- "Materialist"--was at pains to show that cybernetics serves the "war god." While admitting the technological usefulness of computer and control systems, he said:

"The theory of cybernetics, attempting to extend the principles of operation of the most recently constructed computers to quite distinct natural and social phenomena without regard for their qualitative uniqueness, is mechanisticism transformed into idealism. It is a sterile flower on the tree of knowledge generated as a result of the one-sided and unbounded exaggeration of one of the demons of knowledge."

Materialist's definitions of cybernetics are also interesting. At one point he called cybernetics a "misanthropic pseudotheory"; at another he said, "Cybernetics is one of those pseudosciences which are generated by contemporary imperialism and are doomed to failure even before the downfall of imperialism."

However, it was not cybernetics but rather Materialist's attack on it that was doomed to failure before the downfall of imperialism. The other two events of 1953--the production of the BESM (and other computers such as the TESM-1, M-2, M-3, STRELA, etc.) and Stalin's death--seem to have played a large role in dooming Materialist's attitude. Though the details are not clear, Materialist's attack was not followed up; after it, the tone seemed to change.

No events of significance for Soviet cybernetics appeared on the surface in 1954, but there must have been ferment below the surface, for in 1955 the complexion of Soviet cybernetics changed.

* Questions of Philosophy, No. 5, 1953, pp. 210-219.

First, in the pages of the same Questions of Philosophy which had contained Materialist's attack, there appeared an article by three professors at Moscow University-- S. L. Sobolev, a distinguished mathematician, A. A. Lyapunov, a programming theorist, and A. I. Kitov, a computer specialist--entitled "Basic Traits of Cybernetics."^{*} It was a careful and conservative description of cybernetics which avoided drawing inferences about its potential impact on psychology, sociology, or economics. But it also condemned those who had called cybernetics a "pseudoscience" and exonerated Wiener of the excesses of some of his Western disciples.

Second, in the 1955-56 academic year, a seminar on cybernetics was begun at Moscow University. Although devoted primarily to a review of Western work, its approach was clearly positive (namely, to bring together representatives of diverse professions and establish a common cybernetic viewpoint). The objective was to learn and not to criticize. Attending the seminar were many who have subsequently become prominent in Soviet cybernetics--a number of the most competent mathematicians and physiologists in the Soviet Union. Moscow University is the crown of Soviet education and its mathematics faculty is among the two or three best groups of mathematicians in the world. It is there, apparently, that much of the original enthusiasm for cybernetics was generated. Lyapunov and Sobolev played, and continue to play, pivotal roles in its development.

The acceptance of cybernetics at Moscow University was far from complete, however. The outstanding mathematician,

^{*}Questions of Philosophy, No. 4, 1955, pp. 136-147.

A. N. Kolmogorov, gave a speech critical of cybernetics in October of the following year, 1956. But, as the events of 1957 show, that attitude was soon to change. The year 1956 in other respects witnessed a continuing, though hesitant, growth of Soviet acceptance of cybernetics. The Lenin Library--which corresponds to the Library of Congress--published a 23-page survey of recommended literature on cybernetics and its applications. Soviet delegates attended the first UNESCO-sponsored conference on cybernetics, held at Namur, Belgium. And a trickle of popular literature on cybernetics began to appear.

In 1957, Kolmogorov reversed his previous stand against cybernetics, saying that he had been misled by the irresponsible claims of the Western press. His support, which has continued, must have been an important victory for the cyberneticists, for he is Dean of the Faculty of Mathematics and Mechanics at Moscow University and he almost certainly wields great influence in the Academy of Sciences. Kolmogorov has gone on to adopt an extreme position in the mind-machine controversy; he said recently, "Artificial thinking beings are possible. It is not worth arguing whether it is possible to create them in principle."*

Also in 1957, the Laboratory of Electromodeling of the Academy of Sciences, headed by L. I. Gutenmakher, held a scientific-technical conference on cybernetics which was attended by 500 scientists from 90 different organizations. The conference was primarily concerned with problems of computer information storage and retrieval and machine

* Cited from Nedelya by V. Gukov, "Thinking Machines and Man," USSR, No. 5(80), May 1963, p. 50.

translation of languages. The discussions covered the range from logic and linguistics to computer programming and components. During the 1956-57 school year, the cybernetics seminar at Moscow University continued. Its meetings became more frequent and more devoted to original Soviet work. Finally, in 1957 the first Sputnik was launched--undoubtedly with the assistance of the cyberneticists' computers.

The serious Soviet scientific literature on cybernetics made its first appearance in 1958, only six years ago. In that year, Vol. 1 of Problems of Cybernetics [Problemy kibernetiki], a hard-bound, irregularly published collection of articles on all aspects of cybernetics, appeared under the editorship of A. A. Lyapunov. Since that time nine additional volumes have been published. Articles on computer theory and design, switching theory, automatic programming, theory of games, mathematical economics, biological and psychological problems, and machine translation of languages have appeared; the technical quality has been uniformly high. Also in 1958, Norbert Wiener's book was published in a Russian edition.

Six years after Materialist's attack, and Stalin's death, cybernetics achieved full acceptance by the scientific-governmental hierarchy: on April 10, 1959, the Academy of Sciences established the "Scientific Council for the Complex Problem of Cybernetics." Placed at its head was Academician Aksel I. Berg, an expert on radio engineering, an Admiral in the engineering branch of the Soviet Navy, a member of the Communist Party, and a former Deputy Minister of Defense. Among the members of the Council were engineers, economists,

biologists, linguists, designers, and workers in different branches of the national economy. The task of the Cybernetics Council is to coordinate the development of cybernetics in the Soviet Union. It has taken over sponsorship of the journal Problems of Cybernetics and of a number of conferences on various aspects of cybernetics. Recently, the council has been reorganized and split into two sections. One, devoted to the physical, biological, and technical sciences, is headed by B. V. Gnedenko, a prominent mathematician. The other, devoted to the sensitive humanities and social sciences (which includes law, linguistics, economics, psychology, and pedagogy), is headed by a lawyer, D. A. Kerimov.

The growth of Soviet cybernetics since 1959 is reflected in the publication explosion that it has unleashed. Besides the papers on cybernetic subjects in established journals, new journals and sections of journals devoted entirely to cybernetics have appeared.

In 1960, for example, one of the most prominent scientific journals in the Soviet Union, the Transactions of the Academy of Sciences [Doklady Akademii nauk], introduced a section on "Cybernetics and Control Systems." Reports on progress in theoretical aspects of cybernetics appear regularly in that section. (Other sections include: Mathematics, Technical Physics, Biophysics, Crystallography, and so on.)

Also in 1960 a series of hard-cover translations of Western works in cybernetics, Cybernetics Collection [Kiberneticheskij sbornik], made its appearance. Six volumes have been issued thus far.

In 1961, cybernetics' service to Communism was the major theme. A collection of articles describing the prospective achievements of cybernetics was issued under the editorship of A. I. Berg. Its title, Cybernetics--In Communism's Service, could be taken as an answer to Materialist's 1953 attack, "Whom Does Cybernetics Serve?"

1961 also saw the publication of a collection of articles entitled Philosophical Problems of Cybernetics. The articles were the texts of speeches presented by the participants in a series of discussions in 1958-59 on the disputed questions of cybernetics under the aegis of the Department of Philosophy of the Academy of Social Sciences under the Central Committee of the Communist Party of the Soviet Union and the Institute of Automation and Remote Control of the Academy of Sciences. Some hesitant approaches to the resolution of conflicts between Marxism-Leninism and cybernetics are present in the articles, but some of the most important problems are left unstated, let alone resolved.

Finally, in 1961 the Program of the Communist Party of the Soviet Union adopted by the 22nd Party Congress pointed out that in the course of the next 20 years cybernetics, electronic computers, and control systems will be widely applied in production processes in industry, building, and transport, in scientific research, planning, designing, accounting, statistics, and management. Cybernetics had achieved support at the highest level of national affairs; there was no longer any doubt as to its acceptance.

In 1962, the Reference Journal--Mathematics [Referativnij zhurnal--matematika], the Soviet equivalent of

Mathematics Reviews, began a section on Cybernetics. Included within it are subsections on general questions, theory of controlling systems, automatic control, theory of mathematical machines, information theory, linear programming and mathematical economics, theory of games and operations research, biological and psychological problems, and linguistic problems. It presents a very thorough coverage of Soviet and Western publications on cybernetics. Beginning in 1964, a separate reference journal entirely devoted to cybernetics was established.*

In 1963, the Bulletin [Izvestia] of the Academy of Sciences, Technical Section, started publication of a new journal, Engineering Cybernetics [Tekhnicheskaya kibernetika], devoted to all aspects of automatic control, information theory, adaptive systems, computer design, and reliability theory. In April 1964, the Lenin Prize was given to two outstanding cybernetists, V. M. Glushkov and M. A. Ajzerman.

This then is a skeletal survey of the development of Soviet cybernetics to date. Its impetus and support is great and its prospect for continued development is good. It is of the greatest importance for Western scientists, engineers, and Sovietologists to maintain a continuing watch over it.

PROMISE AND PROBLEMS

Cybernetics has for the Soviets both promise and problems. It can provide the technology for industrial

* Reference Journal--Cybernetics [Referativnij zhurnal--kibernetika].

and managerial progress and the impetus for ideological and political revolution. Its evolution during the coming years, therefore, will have great importance for the Soviets and for the West.

What is cybernetics' promise? It is threefold: improved military and civilian technology, rationalization of the economy, and mechanization of intellectual tasks. Let us consider each one in turn.

The most obvious and undisputed value of cybernetics is in the area of its birth: computers, automatic control systems, and communication systems. As technical (or engineering) cybernetics--as the Soviets call this area--progresses, it provides the capability for automation and increased productivity of industrial processes, for remote control, for adaptive, self-organizing, and optimal control systems, for automation of the educational process through the use of teaching machines, for the control of complex processes and systems, for high-speed communication and computation; in brief, for all the benefits promised by the so-called Second Industrial Revolution. Translated into politico-economic terms, it provides the technology to support high and increasing levels of production and the national power that goes with it. The close reliance of contemporary military technology on the fruits of cybernetic research--computers, command and control, guidance, communications, intelligence--is evident.

The Soviets have also grasped the important prospects of cybernetic developments for the rationalization of the complex managerial bureaucracy necessary in a large planned economy. Admiral Berg has said:

"...As distinct from the capitalist countries, where the various firms create, each for itself, separate automated systems of control, under socialism it is perfectly possible to organize a single complex, automated system of control of the country's national economy. Obviously, the effect of such automation will be much greater than that of automating control of individual enterprises."*

In November 1961, a coordinating conference on questions involved in the application of mathematical methods and electronic computing machines in economic research and planning was held in Moscow. Emphasis was placed on the rational organization of economic information, on the computerization of parts of the planning process, and on the uses of optimization techniques in planning and management. Examples were given of large improvements in production and transportation projects that had been obtained by optimization techniques. It is planned to develop regional computer centers throughout the Soviet Union, and, eventually, to link them with the central facilities in Moscow. Western experience with operations research and business data processing indicates that benefits, as well as some deficits, may be expected from Soviet developments in this area.

The third, and least developed, region of promise for cybernetics is the mechanization of intellectual tasks. Roughly speaking, this region divides into two parts: information analysis and information synthesis.

* Cited by Olgin, C., "Soviet Ideology and Cybernetics," Bulletin of the Institute for the Study of the USSR, February 1962, from Kommunist, Vol. 37, No. 9, June 1960, p. 23.

Under information analysis are included those tasks in which the high speed and large memory of computers is being used to operate on available information so as to bring it to more convenient form. The so-called "science information problem" would be a principal beneficiary of progress in this field, which includes document retrieval, automatic abstracting and indexing, and automatic language translation. Military intelligence would also benefit.

Under information synthesis are included those tasks in which computers operate on available information to produce information not hitherto available. Machine inference-making, learning, and pattern recognition are examples of such tasks. The distinction between information analysis and synthesis is evidently not clear-cut. And the beneficiaries of progress in information synthesis would include those benefiting from information analysis. But there is a qualitative difference that will undoubtedly lead to valuable applications as yet only indistinctly seen. Soviet developments in this area can be of the greatest importance in intelligence, command and control, management, planning, and science.

But cybernetics also presents problems. The basic problem is that cybernetics emphasizes the qualitative similarity of the processes of control and communication in man, machine, and society and suggests that those processes may be quantified. In its potentially universal applicability, cybernetics challenges Marxism-Leninism and the omniscience which the Communist Party leaders, as sole interpreters, claim. Marxism-Leninism, the Soviet ideologists contend, comprises the most general laws

governing the evolution of the material world and human society. As an emigre student of the Soviet Union has observed:

"...cybernetics...might easily result in the rise of a rival philosophy and, at the very least, encourage the devotees of cybernetics to query, first the laws of Dialectical, then those of Historical Materialism, and finally the omniscience of the Central Committee, not in the natural sciences, which Khrushchev's administration had already virtually liberated from Party tutelage, but in economics, sociology and possibly even politics, where this tutelage must be preserved at all costs."*

Moreover, the evident successes of cybernetics in treating control and communication processes in machines makes its potential for studying man and society even more threatening and more difficult to ignore. This then is the essence of the problem. Its actuality, however, takes at least five forms.

First, there is the problem that arises from cybernetics' claim to provide one basis for development of a theory of society. But Marxism-Leninism, and Historical Materialism in particular, is already supposed to be a completed theory of society that provides "objective laws of social development independent of the will and consciousness of the people." This problem may not turn out to be as great as it could be; some of the ideologists are trying to smooth over the potential conflicts. At a conference on the Philosophical Problems of Cybernetics, held in June 1962, several reports were devoted to the social aspects of cybernetics and its application to social sciences. The

*Olgin, op. cit., p. 7.

reports included an examination of the application of the theory of games to social phenomena, a discussion of the need to study the circulation of information in society, and a plea to attract cybernetics to the solution of problems connected with the control of human society.

Second, there is the problem that arises from the claim of some cyberneticians that machines can be made to "think." This is, of course, also a source of controversy in the West, but it does not strike at the tenets of any Western ideology holding a position comparable to that held by Marxism-Leninism in the Soviet Union. Thus, the Marxist materialist ideology states that the world is composed of various forms of matter in motion and that it is futile to transfer forms of motion peculiar to one form of matter to qualitatively distinct forms of matter where other, higher principles operate. In other words, there is a qualitative difference between a living organism and a machine that can never be removed. Machines can never take part in intellectual processes, a form of motion, because that form is peculiar to man. Such is the ideological argument that could be made, if the government and ideologists so desired. It was made in the 1953 Materialist attack, but recent debate on this point, interestingly, has been very free. The 1962 conference on philosophical problems was devoted almost entirely to discussions of this issue and all sides were represented. As has been noted earlier, Kolmogorov has adopted the extreme cyberneticists' position.

Third, there is the problem posed for traditional Soviet psychology by the developments associated with

cybernetics. Soviet psychology has developed along much more restricted lines than has Western psychology. Much of it has been based on the reflex notions originated by Pavlov and Sechenov. Cybernetics has opened vistas of machine simulation of problem-solving and linguistic behavior, of the formal analysis of nerve-nets and brain functions, of human engineering and engineering psychology, of studies of perception, thought, and creation. The problem for Soviet psychology is to absorb those aspects of modern psychology, such as human engineering and the simulation of problem-solving behavior, that can be of practical and theoretical use, without undermining the authority of the traditional, ideologically based studies.

Fourth, there are the problems posed for Marxian economics by the application of mathematics and computers to planning, data collection, and management. Soviet interpretation of cost, profit, price, demand, and related ideas differ considerably from Western notions. Western economists have often noted the investment inefficiencies resulting from the Marxian labor theory of value and its corollary that there should be no interest charges for capital. Soviet statistical and bookkeeping practices have fallen prey to all the problems of a large bureaucracy. Quality of production has suffered from the natural tendencies of a system where reward is based on the fulfillment of a quantitative plan. Central planning has labored under the burden of coordinating a vast system of interconnected enterprises subject to fluctuations, changes, and failures. When the strict logic of mathematical economics and the rigid information demands of

digital computers are imposed on this vast body of bureaucratic procedures and qualitative dogmatic concepts, the prospect of conflict among the cyberneticists, the bureaucrats, and the ideologists becomes a very real threat.

Finally, cybernetics offers a banner under which scientists may pursue efforts to expand the domain and influence of science. Through its successes in automation, space, and economic affairs, cybernetics has achieved acceptance as a positive force for the development of the Soviet economy and of Communism. Now scientists are basing some of their attacks on outmoded Lysenko-ist genetics on cybernetic models of information transfer in the cell. The challenges in social theory, psychology, and economics have been noted. But there are prospects, as well, for further challenges, for challenges to the authority of the Communist Party, for challenges to the organization and implementation of control and information gathering in society. Those challenges can only be glimpsed at present--and they may not develop further--but their prospect is one of the most fascinating aspects of the development of cybernetics in the Soviet Union.

BIBLIOGRAPHY OF RAND CORPORATION PUBLICATIONS IN
SOVIET CYBERNETICS AND COMPUTER TECHNOLOGY

1. Ware, W. H. (ed.), Soviet Computer Technology--1959, RM-2541, March 1, 1960. Reprinted in IRE Transactions on Electronic Computers, Vol. EC-9, No. 1, March 1960.

An account of a trip taken by two RAND computer specialists to the Soviet Union as part of an eight-man delegation representing the U.S. National Joint Computer Committee and its member societies. The genesis of the delegation and its itinerary in the Soviet Union are traced. The state of the art in Soviet computer technology as observed by the delegates is examined, showing the development, constructions, applications, routines, and components of the major Soviet computing machines. Impressions are included on Soviet education, the role of the Academy of Sciences, and Chinese developments in computer technology. Many photographs of Soviet machines, components, people, and places are included. First-hand information is also given on the BESM-I, BESM-II, Strela, Ural, and Kiev computers, plus several other machines. Machine specifications are presented in chart form, facilitating comparisons; op codes are given for the Ural-1 and Ural-2. 205 pp. Illus.

2. Feigenbaum, E. A., Soviet Cybernetics and Computer Sciences, 1960, RM-2799-PR, October 1961. Reprinted in IRE Transactions on Electronic Computers, Vol. EC-10, No. 4, December 1961.

A description of the author's experiences as a delegate to the International Congress on Automatic Control, held in Moscow, June 27-July 7, 1960. The Memorandum discusses: (1) certain aspects of the conference; (2) some Soviet research projects in artificial intelligence and biocybernetics; and (3) general Soviet attitudes, techniques, and directions in the cybernetic and computer-related sciences. It is concluded that Soviet research in the computer sciences lags behind Western developments, but that

the gap is neither large nor based on a lack of understanding of fundamental principles. The Soviets will progress rapidly if and when priority, in terms of accessibility to computing machines, is given to their research. 77 pp. Illus.

3. Krieger, F. J., Soviet Philosophy, Science, and Cybernetics, RM-3619-PR, April 1963.

A discussion of how all aspects of science--i.e., knowledge--are made to conform to the ideological mold of Marxism-Leninism in the Soviet Union. The larger part of the Memorandum consists of a thematic plan from the Soviet journal Questions of Philosophy [Voprosy filosofii], which lists over 300 topics suggested for discussion and study in the Soviet-planned society. 27 pp.

4. Ware, Willis H., and Wade B. Holland (eds.), Soviet Cybernetics Technology: I. Soviet Cybernetics, 1959-1962, RM-3675-PR, June 1963.

Seven sets of translations in the area of Soviet cybernetics, together with commentary and analyses on the status of cybernetics in the Soviet Union, and the directions of Soviet cybernetics research. This volume is concerned with general computer technology and cybernetics applications, rather than with specific machines. Particular emphasis was placed on selecting items for translation that survey the activities of organizations and conferences, and the current literature. 104 pp. Illus.

5. Ware, Willis H., and Wade B. Holland (eds.), Soviet Cybernetics Technology: II. General Characteristics of Several Soviet Computers, RM-3797-PR, August 1963.

Several sets of translations detailing specifications for the Ural-2, Ural-4, BESM-II, Razdan-2, MN-10 and MN-14, Luch, and EPOS computers. The level of detail varies widely among the several articles, which were taken from such diverse sources as specification brochures, items in the popular press, technical journals, etc. Included is a set of instructions for the BESM-II which is quite dissimilar to that presented in Elements of Programming (see Vol. III in this series). 67 pp. Illus.

6. Ware, Willis H., and Wade B. Holland (eds.), Soviet Cybernetics Technology: III. Programming Elements of the BESM, Strela, Ural, M-3, and Kiev Computers, Translated by A. S. Kozak, RM-3804-PR, September 1963.

A translation from the Russian book Elements of Programming, detailing the instruction formats for five of the better known Soviet digital computers. Some notes are included to help place the machines in perspective. Specially-prepared charts give the operation codes for the five machines, along with the original Russian terminology and its English translation. 91 pp. Illus.